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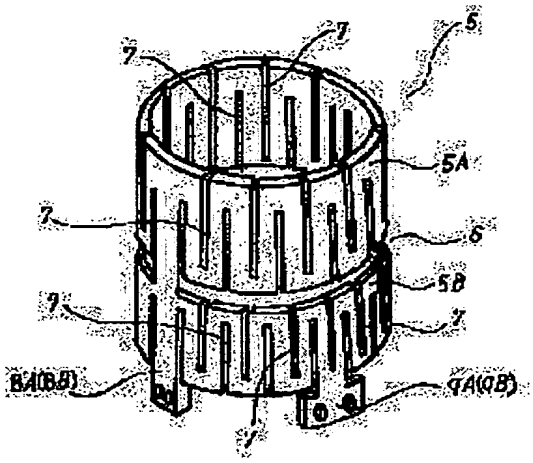
(54) APPARATUS FOR SINGLE CRYSTAL

(57)Abstract:
PROBLEM TO BE SOLVED: To provide an apparatus for producing a single crystal with which the lowering of the oxygen concn. of the single crystal under pulling up is made possible, and further, the stable melting of the polycrystalline raw materials held in a crucible is made possible and which is low in cost and for which the installation space is suppressed to the possible min. extent.
SOLUTION: A hollow cylindrical heating element 5 which coaxially encloses the crucible is provided with toric slits 6 approximately perpendicularly to the axial direction exclusive of at least two points of electrode parts along the hollow cylindrical straight barrel part thereof. This heating element 5 is divided to an upper heat generating section 5A and a lower heat generating section 5B. The respective upper and lower heat generating sections 5A, 5B are provided with plural pieces of such perpendicular slits 7 which are approximately parallel with the axial direction and are alternated from both upper and lower directions. The pitches of the perpendicular slits 7 of the heating element 5 are respectively varied by the upper heat generating section 5A and the lower heat generating section 5B. The thickness or length of the hollow cylindrical barrel part of the heating element 5 is varied with the upper heat generating section 5A and the lower heat generating section 5B, respectively.



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CLAIMS

[Claim(s)]
[Claim 1] The single crystal manufacturing installation characterized by preparing two or more perpendicular slits which divide this heating element into the up exoergic section and the lower exoergic section by preparing a slit in a circle in shaft orientations and an abbreviation right angle except for at least two polar zone in alignment with the hollow cylinder shaft drum section in the bell shape heating element by the resistance heating which surrounds crucible in same axle, and become more nearly alternate than vertical both directions by shaft orientations and abbreviation parallel at the exoergic section of each of these upper and lower sides.
[Claim 2] The perpendicular slit of said heating element is a single crystal manufacturing installation according to claim 1 which is that from which the pitch differs by the up exoergic section and the lower exoergic section, respectively.
[Claim 3] The single crystal manufacturing installation according to claim 1 or 2 which is that from which the thickness or die length of a hollow cylinder drum section of said heating element differs in the up exoergic section and the lower exoergic section, respectively.
[Claim 4] claim 1 which has at least four polar zone in said lower exoergic section thru/or 3 -- a single crystal manufacturing installation given in either.
[Claim 5] Said heating element is a single crystal manufacturing installation according to claim 4 which has two lower exoergic section electrodes in a lower exoergic sections side other than two common electrodes common to the up exoergic section and the lower exoergic section, and this common electrode, and has the modification means of a current path which can respond, respectively when passing heating current to this lower exoergic section electrode and common inter-electrode [said], and when passing heating current among said common electrodes.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the single crystal manufacturing installation which made it possible to dissolve in stability the polycrystal raw material held to crucible for the purpose of reducing the oxygen density of semiconductor single crystals, such as silicon mainly manufactured by the Czochrlski method (CZ process).
[0002]
[Description of the Prior Art] As conventionally indicated by JP,4-305087,A The upper case section, The thickness of this upper case section of the heater 8 constituted by an inside step and three steps of lower-berth sections and an inside step is formed more thinly than the lower-berth section. this upper case section and the middle -- the calorific value by the resistance heating of the section -- the lower-berth section -- large -- carrying out -- this -- the middle -- there is a configuration with a peak of exoergic distribution for a while from the oil level of this melting liquid 6 in the upper location by locating the oil level of melting liquid 6 below for a while rather than the center of the section. Moreover, a tank bottom heater 4 is arranged for the side heater 3 between crucible 2 and heat insulating material 5 again at the lower part of crucible 2, and the configuration to which the output control of each heater 3 and 4 was carried out independently is known as indicated by JP,2-192486,A.
[0003]
[Problem(s) to be Solved by the Invention] However, in the conventional example, in the case of the technical contents indicated by JP,4-305087,A, the thickness of the heater upper case section is partially written small so that the peak of exoergic distribution may be located in the upper part of a resistance heating heater, this part is remarkably eroded by SiC-izing and oxidation by the SiO dust generated from a melt side, and the life of a heater will be shortened. Moreover, it had the trouble of leaving so much fungoid, with the raw material upper part not dissolving when dissolving the polycrystal material as a raw material within quartz crucible, only the lower part dissolving, damaging quartz crucible when balance is lost and a fall fall is carried out, as this was the dissolution, and making single crystal manufacture impossible. Moreover, since equipment itself became large-scale, and the cost of a single crystal manufacturing installation went up and the power source and the temperature controller were also used 2 sets in order to use two independent heaters and the independent power source in the case of the technical contents indicated by JP,2-192486,A, it had the trouble that an installation tooth space will also become large.
[0004] It aims at offering the single crystal manufacturing installation which is the low cost which enabled it to have made this invention in view of the above-mentioned trouble, to make erosion by oxidation of the exoergic section mitigate, and to lengthen the life of the exoergic section, and to make low the oxygen density of the single crystal under raising, and made it possible to dissolve further the polycrystal raw material held to crucible in stability, and stopped an installation tooth space to the minimum.
[0005]
[Means for Solving the Problem] If it is in this invention in order to attain the purpose mentioned above In the bell shape heating element by the resistance heating which surrounds crucible in same axle This heating element is divided into the up exoergic section and the lower exoergic section by preparing a slit in a circle in shaft orientations and an abbreviation right angle except for at least two polar zone in alignment with the hollow cylinder shaft drum section. It is characterized by preparing two or more perpendicular slits which become more nearly alternate than vertical both directions by shaft orientations and abbreviation parallel at the exoergic section of each of these upper and lower sides.
[0006] Moreover, the pitch shall change with the up exoergic section and lower exoergic sections, respectively, or the perpendicular slits of said heating element shall differ in the thickness or die length of a hollow cylinder drum section of said heating element in the up exoergic section and the lower exoergic section, respectively. Furthermore, it can also

consider as the configuration which ha[redacted]least four polar zone at said lower exoe[redacted]section.
[0007] In addition, said heating element is good also as a configuration which has two lower exoergic section electrodes in a lower exoergic sections side other than two common electrodes common to the up exoergic section and the lower exoergic section, and this common electrode, and has the modification means of a current path which can respond, respectively when passing heating current to this lower exoergic section electrode and common inter-electrode [said], and when passing heating current among said common electrodes.
[0008] If it is in the single crystal manufacturing installation concerning this invention, 2 ****s is carried out by the slit in a circle, and the up exoergic section and the lower exoergic section which prepared the perpendicular slit, respectively are switched by the modification means of a current path, when making only the lower exoergic section heat, and when adding 4 times as much power as the lower exoergic section to the up exoergic section. At the time of the dissolution of the polycrystal raw material within crucible, the peak of exoergic temperature distribution is located to a crucible lower part side by making only the lower exoergic section heat by this, and a polycrystal raw material is dissolved in stability from the bottom. Moreover, it is made to make it the peak of exoergic temperature distribution located in the crucible upper part at the time of single crystal growth, mainly using the up exoergic section, and manufacture of the semi-conductor single crystal of hypoxia concentration is enabled.
[0009]
[Embodiment of the Invention] Hereafter to explain the gestalt of operation of this invention with reference to a drawing drawing 1 In the explanatory view showing the condition of having been filled up with the polycrystal ingredient which is a raw material of a semi-conductor single crystal in crucibles, such as a quartz of the single crystal manufacturing installation which mainly manufactures semi-conductor single crystals, such as silicon, with the Czochrlski method (CZ process) The quartz crucible 3 is attached in the graphite crucible 2 which was supported with the crucible shaft 1 and installed in the Maine chamber, and it fills up with the polycrystal ingredient 4 in this quartz crucible 3. 5 is a bell shape heating element by the resistance heating made to surround in same axle around both the crucibles 2 and 3, and as shown in drawing 2 , except for at least two polar zone (common electrode mentioned later) in alignment with the hollow cylinder shaft, the slit 6 in a circle is formed in shaft orientations and an abbreviation right angle, and it is taken as the configuration which divided this heating element 5 into up exoergic section 5A and lower exoergic section 5B by this.
[0010] Moreover, two or more perpendicular slits 7 which become more nearly alternate than vertical both directions by the shaft orientations and abbreviation parallel are formed in the exoergic sections 5A and 5B of each of this up lower part. And in order that this perpendicular slit 7 may change each electric resistance, that pitch shall change, respectively with up exoergic section 5A and lower exoergic section 5B. Furthermore, in order to make the location of the peak of exoergic temperature distribution change in the time of the dissolution of a polycrystal ingredient and raising of single crystal manufacture between up exoergic section 5A and lower exoergic section 5B, the thickness or die length of a hollow cylinder drum section of a heating element 5 shall be different, respectively by up exoergic section 5A and lower exoergic section 5B, and the calorific value based on the resistance heating is made to differ.
[0011] Two common electrodes 8A and 8B common to up exoergic section 5A and lower exoergic section 5B to said heating element 5, When the this common electrode 8A and lower exoergic section 5B side other than 8B is equipped with two lower exoergic section electrodes 9A and 9B and heating current is passed to these lower exoergic section electrodes 9A and 9B, said common inter-electrode 8A, and 8B, When passing heating current between said common electrode 8A and 8B, the modification circuit 10 which constitutes the modification means of a current path which can respond, respectively is formed. As this modification circuit 10 is shown in drawing 3 , a gate turn-off thyristor shall specifically perform. By considering as the configuration to which Thyristors a and b were connected between lower exoergic section electrode 9A and 9B, and Thyristors c and d were connected between common electrode 8A and 8B The current path of said common electrodes 8A and 8B as shown in the following table 1, and the lower exoergic section electrodes 9A and 9B was made to have divided and changed based on switch change-over actuation of the thyristors a, b, c, and d by the following table 2 at the time of the dissolution and raising. 15 is a power source for heating element 5 heating.
[0012]
[Table 1]

(発熱体の電流経路)

	溶解時	引上時
電極	電圧	電圧
①	+E	+E
②	+E	−E
③	−E	OPEN
④	−E	OPEN

[0013]
[Table 2]
(ゲートターンオフサイリスターのスイッチ切換動作)

	溶解時	引上時
ⓐ	ON	OFF
ⓑ	ON	OFF
ⓒ	ON	OFF
ⓓ	OFF	ON

[0014] Namely, it sets at the time of the dissolution of the polycrystal ingredient P. Make it this potential (+E), and a current does not flow to up exoergic section 5A, and does not make it heat the common electrodes 8A and 8B. Set up so that only lower exoergic section 5B may be made to heat, and it sets at the time of raising of single crystal manufacture. The potential difference (2E) is established common electrode 8A, common electrode 8B, and in between, the lower exoergic section electrodes 9A and 9B are changed into an off condition, and up exoergic section 5A and lower exoergic section 5B are set as the parallel connection condition. At this time, by the difference in the pitch of the thickness of said up exoergic section 5A and lower exoergic section 5B, the difference in die length, or the perpendicular slit 7 of up exoergic section 5A and lower exoergic section 5B etc. For example, if the electric resistance of up exoergic section 5A is set up so that it may become smaller than the electric resistance of lower exoergic section 5B, as for the peak of a large next door, consequently exoergic temperature distribution, the calorific value of up exoergic section 5A will be located in an upper part side rather than lower exoergic section 5B.
[0015]
[Example] A 150kW thing is used for the output of the power source 15 of up exoergic section 5A and lower exoergic section 5B at the time of a 25mohm load. The outer diameter of up exoergic section 5A and lower exoergic section 5B which form said heating element 5 phi620mm, The die length of 260mm and lower exoergic section 5B for the die length of phi576mm and up exoergic section 5A 220mm, [a bore] Between the terminals between 20mm of breadths of the slit 6 in a circle, common electrode 8A, and 8B, resistance 20mohm, 1/2 of up exoergic section 5A and thickness of lower exoergic section 5B are set to one half of up exoergic section 5A for pitch spacing of the perpendicular slit 7 of resistance 25mohm and lower exoergic section 5B between the terminals between the common electrodes 8A and 8B and the lower exoergic section electrodes 9A and 9B. When the electric resistance of lower exoergic section 5B was set up by 4 times the up exoergic section 5A, as the calorific value of up exoergic section 5A would be 4 times the lower exoergic section 5B and it was shown in the relation between the oxygen density of drawing 4 , and crystal-pulling die length, it was checked that the single crystal of hypoxia concentration is obtained. As a result of impressing the electrical potential difference of -28V between common electrode 8A and 8B between +28V and lower exoergic section electrode 9A and 9B at the time of the dissolution of the polycrystal ingredient 4 and making lower exoergic section 5B specifically consume 125kW, the polycrystal ingredient was able to be dissolved in stability. moreover -- the time of raising -- common electrode 8A -- +21V -- common -- as a result of impressing the electrical potential difference of -21V to electrode 8B and making up exoergic section 5A consume 17kW to 71kW and lower exoergic section 5B, the semi-conductor single crystal was able to be pulled up to stability. At this time, the single crystal outer diameter which was able to pull up the 75kg of the amounts of material charges was phi206mm, and weight was 68kg.

[0016] In addition, although various numeric values are set up as mentioned above, this invention is enabled to make low the oxygen density of the single crystal under raising and it makes it possible to dissolve further the polycrystal ingredient 4 held to crucible in stability, of course in the gestalt of this operation, it is not limited to these numeric-values conditions.

[0017]

[Effect of the Invention] This invention is constituted as mentioned above, and especially, at the time of the polycrystal raw material dissolution within crucible, in order to make only the lower exoergic section heat, it makes it possible to dissolve gradually the polycrystal raw material held to crucible in stability from the bottom. Moreover, since big power joins the up exoergic section so that the peak of exoergic distribution may be located in the upper part, the inside of crystal pulling can make the oxygen density of a single crystal low, and can make erosion by oxidation of the exoergic section able to mitigate, and can lengthen the life of the exoergic section. Furthermore, it is low cost in equipment itself, and an installation tooth space can be stopped to the minimum.

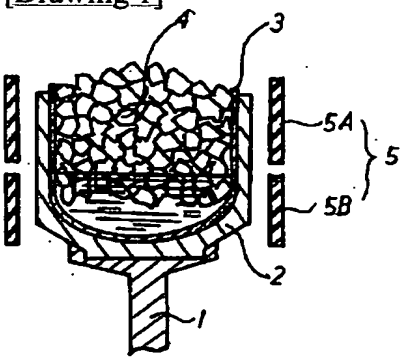
[Translation done.]

* NOTICES *

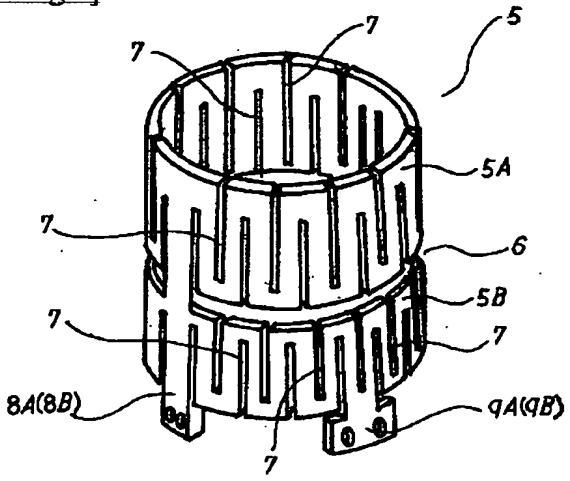
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

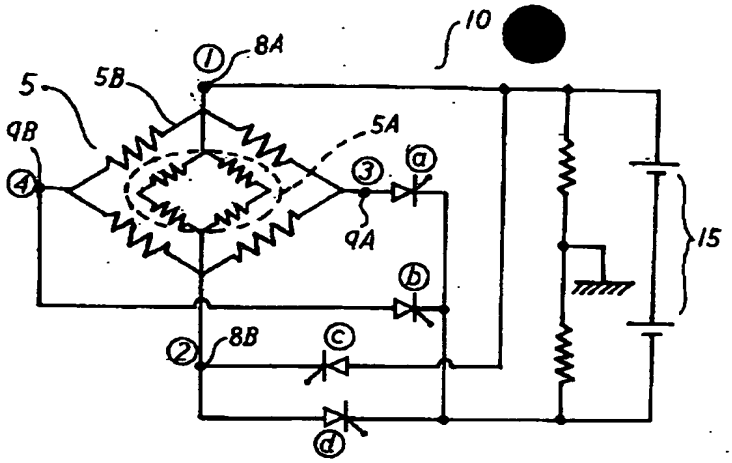
[Drawing 1]



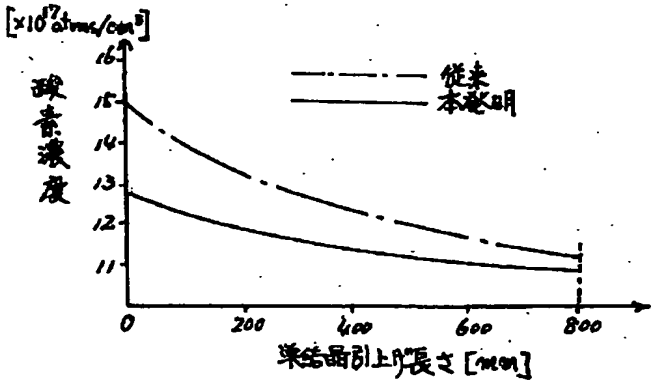
[Drawing 2]



[Drawing 3]



[Drawing 4]



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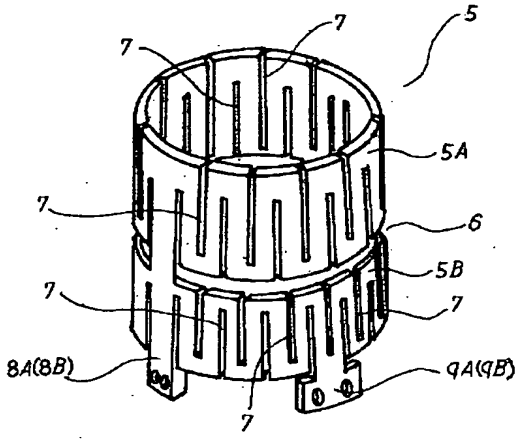
(54)【発明の名称】　単結晶製造装置

(57)【要約】

【課題】　引上中の単結晶の酸素濃度を低くすることを可能とし、さらに、坩堝に保持した多結晶質原料を安定に溶解することを可能とした低コストで且つ設置スペースを最小限に抑えた単結晶製造装置を提供する。

【解決手段】　坩堝を同軸的に包囲する中空円筒状の発熱体５の中空円筒軸胴部に沿った少なくとも２箇所の電極部を除いて軸方向と略直角に円環状スリット６を設け、該発熱体５を上部発熱部５Ａと下部発熱部５Ｂとに分割し、該上下夫々の発熱部５Ａ，５Ｂに軸方向と略平行で上下両方向より互い違いとなるような複数個の垂直スリット７を設ける。発熱体５の垂直スリット７は、そのピッチが上部発熱部５Ａと下部発熱部５Ｂによって夫々異なるものとする。また、発熱体５の中空円筒胴部の肉厚または長さを上部発熱部５Ａと下部発熱部５Ｂとで夫々異なるものとする。



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【特許請求の範囲】

【請求項１】　坩堝を同軸的に包囲する抵抗加熱による中空円筒状の発熱体において、その中空円筒軸胴部に沿った少なくとも２箇所の電極部を除いて軸方向と略直角に円環状スリットを設けることで該発熱体を上部発熱部と下部発熱部とに分割し、該上下夫々の発熱部に軸方向と略平行で上下両方向より互い違いとなるような複数個の垂直スリットを設けたことを特徴とする単結晶製造装置。

【請求項２】　前記発熱体の垂直スリットは、そのピッチが上部発熱部と下部発熱部によって夫々異なるものである請求項１記載の単結晶製造装置。

【請求項３】　前記発熱体の中空円筒胴部の肉厚または長さが上部発熱部と下部発熱部とで夫々異なるものである請求項１または２記載の単結晶製造装置。

【請求項４】　前記下部発熱部には少なくとも４つの電極部を有する請求項１乃至３いずれかに記載の単結晶製造装置。

【請求項５】　前記発熱体は上部発熱部と下部発熱部とに共通な２つの共通電極と、該共通電極以外の下部発熱部側に２つの下部発熱部電極とを有し、該下部発熱部電極と前記共通電極間に加熱電流を流す場合と、前記共通電極同士の間に加熱電流を流す場合とに夫々対応できる電流経路の変更手段を有する請求項４記載の単結晶製造装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、主にチョクラルスキー法（ＣＺ法）により製造されるシリコン等の半導体単結晶の酸素濃度を低減することを目的とし、坩堝に保持した多結晶質原料を安定に溶解することを可能とした単結晶製造装置に関するものである。

【０００２】

【従来の技術】従来、特開平４－３０５０８７号公報に開示されているように、上段部、中段部、下段部に３段構成されたヒータ８の該上段部および中段部の厚みを下段部よりも薄く形成し、該上段部および中段部の抵抗加熱による発熱量を下段部よりも大きくし、該中段部の中央よりも少し下方へ溶融液６の液面を位置させることにより、該溶融液６の液面より少し上の位置で発熱分布をピークにした構成がある。また、特開平２－１９２４８６号公報に開示されているように、坩堝２と保温材５との間にサイドヒータ３が、また坩堝２の下部にボトムヒータ４が配設されて、夫々のヒータ３，４を独立して出力制御させた構成が知られている。

【０００３】

【発明が解決しようとする課題】しかしながら、従来例では、特開平４－３０５０８７号公報に開示された技術内容の場合、発熱分布のピークを抵抗加熱ヒータの上部に位置するようにヒータ上段部の肉厚を部分的に小さくしたため、この部分がＳｉＣ化や、融液面から発生するＳｉＯダストによる酸化により著しく浸蝕され、ヒータの寿命を短くさせてしまう。また、石英坩堝内で原料としての多結晶素材を溶解する時に、原料上部が溶解しないままきのこ状に多量に残して下部だけが溶解し、これが溶解の途中でバランスを崩して落下転倒した時に、石英坩堝を破損して単結晶製造を不可能にさせてしまうという問題点を有していた。また、特開平２－１９２４８６号公報に開示された技術内容の場合、独立した２つのヒータおよび電源を使用するため、装置自体が大掛かりなものとなり、単結晶製造装置のコストが上昇してしまい、また、電源や温度制御装置も２組使用するので、設置スペースも大きくなってしまうという問題点を有していた。

【０００４】本発明は、上記問題点に鑑みなされたもので、発熱部の酸化による浸蝕を軽減させて、発熱部の寿命を長くし、また、引上中の単結晶の酸素濃度を低くすることを可能とし、さらに、坩堝に保持した多結晶質原料を安定に溶解することを可能とした低コストで且つ設置スペースを最小限に抑えた単結晶製造装置を提供することを目的としたものである。

【０００５】

【課題を解決するための手段】上述した目的を達成するため、本発明にあっては、坩堝を同軸的に包囲する抵抗加熱による中空円筒状の発熱体において、その中空円筒軸胴部に沿った少なくとも２箇所の電極部を除いて軸方向と略直角に円環状スリットを設けることで該発熱体を上部発熱部と下部発熱部とに分割し、該上下夫々の発熱部に軸方向と略平行で上下両方向より互い違いとなるような複数個の垂直スリットを設けたことを特徴とする。

【０００６】また、前記発熱体の垂直スリットは、そのピッチが上部発熱部と下部発熱部によって夫々異なるものとしたり、前記発熱体の中空円筒胴部の肉厚または長さが上部発熱部と下部発熱部とで夫々異なるものとすることができる。さらに、前記下部発熱部には少なくとも４つの電極部を有する構成とすることもできる。

【０００７】尚、前記発熱体は上部発熱部と下部発熱部とに共通な２つの共通電極と、該共通電極以外の下部発熱部側に２つの下部発熱部電極とを有し、該下部発熱部電極と前記共通電極間に加熱電流を流す場合と、前記共通電極同士の間に加熱電流を流す場合とに夫々対応できる電流経路の変更手段を有する構成としても良い。

【０００８】本発明に係る単結晶製造装置にあっては、円環状スリットにより２分割され、夫々垂直スリットを設けた上部発熱部と下部発熱部とは、電流経路の変更手段により、下部発熱部だけ加熱させる場合と、上部発熱部に下部発熱部の４倍の電力を付加する場合とに切り換えられる。これにより、坩堝内での多結晶原料の溶解時には、下部発熱部だけ加熱させることで発熱温度分布のピークを坩堝下部側へ位置させ、多結晶原料を下側より

2

安定に溶解させる。また、単結晶成長時には上部発熱部を主に使って、発熱温度分布のピークを坩堝上部に位置するようにさせ、低酸素濃度の半導体単結晶の製造を可能とさせる。

【０００９】

【発明の実施の形態】以下、図面を参照して本発明の実施の形態を説明するに、図１は、主にチョクラルスキー法（ＣＺ法）によりシリコン等の半導体単結晶を製造する単結晶製造装置の石英等の坩堝内に半導体単結晶の原料である多結晶質材料を充填した状態を示す説明図で、メインチャンバー内に坩堝軸１により支持され設置された黒鉛坩堝２に石英坩堝３が嵌着され、この石英坩堝３内に多結晶質材料４が充填されている。５は両坩堝２，３の廻りに同軸的に包囲させた抵抗加熱による中空円筒状の発熱体であり、図２に示すように、その中空円筒軸に沿った少なくとも２箇所の電極部（後述する共通電極）を除いて軸方向と略直角に円環状スリット６が設けられており、これにより該発熱体５を上部発熱部５Ａと下部発熱部５Ｂとに分割した構成としている。

【００１０】また、該上部下部夫々の発熱部５Ａ，５Ｂには、その軸方向と略平行で上下両方向より互い違いとなるような複数個の垂直スリット７が設けられている。そして、この垂直スリット７は、夫々の電気抵抗を異ならせるために、そのピッチが上部発熱部５Ａと下部発熱部５Ｂによって夫々異なるものとしている。さらに、多結晶質材料の溶解時と単結晶製造の引上時とで、上部発＊

＊熱部５Ａと下部発熱部５Ｂとの間で発熱温度分布のピークの位置を変更させるために、発熱体５の中空円筒胴部の肉厚または長さは上部発熱部５Ａと下部発熱部５Ｂとで夫々異なるものとし、その抵抗加熱に基づく発熱量を異なるようにしている。

【００１１】前記発熱体５には、上部発熱部５Ａと下部発熱部５Ｂとに共通な２つの共通電極８Ａ，８Ｂと、該共通電極８Ａ，８Ｂ以外の下部発熱部５Ｂ側に２つの下部発熱部電極９Ａ，９Ｂとを備え、該下部発熱部電極９Ａ，９Ｂと前記共通電極間８Ａ，８Ｂに加熱電流を流す場合と、前記共通電極８Ａ，８Ｂ同士の間に加熱電流を流す場合とに夫々対応できる電流経路の変更手段を構成する変更回路１０が設けられている。具体的には、この変更回路１０は、図３に示すように、例えばゲートターンオフサイリスタにより行なうものとし、下部発熱部電極９Ａ，９Ｂ間にサイリスタａ，ｂを接続させ、また共通電極８Ａ，８Ｂ間に、サイリスタｃ，ｄを接続させた構成とすることにより、下記表２によるサイリスタａ，ｂ，ｃ，ｄのスイッチ切換動作に基づき、下記表１に示すような前記共通電極８Ａ，８Ｂおよび下部発熱部電極９Ａ，９Ｂの電流経路を溶解時と引上時とに分けて変更させたものとしている。１５は発熱体５加熱用の電源である。

【００１２】

【表１】

(発熱体の電流経路)

	溶　解　時	引　上　時
電　極	電　圧	電　圧
①	＋Ｅ	＋Ｅ
②	＋Ｅ	－Ｅ
③	－Ｅ	ＯＰＥＮ
④	－Ｅ	ＯＰＥＮ

【００１３】

※　※【表２】

(ゲートターンオフサイリスターのスイッチ切換動作)

	溶　解　時	引　上　時
ⓐ	ＯＮ	ＯＦＦ
ⓑ	ＯＮ	ＯＦＦ
ⓒ	ＯＮ	ＯＦＦ
ⓓ	ＯＦＦ	ＯＮ

【００１４】すなわち、多結晶質材料Ｐの溶解時においては、共通電極８Ａ，８Ｂを同電位（＋Ｅ）にして、上部発熱部５Ａには電流が流れず加熱させず、下部発熱部５Ｂだけを加熱させるように設定しておき、また、単結晶製造の引上時においては、共通電極８Ａと共通電極８Ｂと間に電位差（２Ｅ）を設け、下部発熱部電極９Ａ，

９Ｂを開路状態にして上部発熱部５Ａと下部発熱部５Ｂとを並列接続状態に設定しておく。このとき、前記上部発熱部５Ａと下部発熱部５Ｂとの肉厚または長さの違い、あるいは上部発熱部５Ａと下部発熱部５Ｂとの垂直スリット７のピッチの違い等により、例えば上部発熱部５Ａの電気抵抗を下部発熱部５Ｂの電気抵抗よりも小さくなるように設定しておけば、上部発熱部５Ａの発熱量が下部発熱部５Ｂよりも大となり、その結果、発熱温度分布のピークは上部側に位置することとなる。

【００１５】

【実施例】上部発熱部５Ａと下部発熱部５Ｂとの電源１５の出力を２５ｍΩ負荷時に１５０ｋＷのものを使用し、前記発熱体５を形成する上部発熱部５Ａと下部発熱部５Ｂとの外径をΦ６２０ｍｍ、内径をΦ５７６ｍｍ、上部発熱部５Ａの長さを２６０ｍｍ、下部発熱部５Ｂの長さを２２０ｍｍ、円環状スリット６の幅員２０ｍｍ、共通電極８Ａ，８Ｂ間の端子間抵抗値２０ｍΩ、共通電極８Ａ，８Ｂと下部発熱部電極９Ａ，９Ｂとの間の端子間抵抗値２５ｍΩ、下部発熱部５Ｂの垂直スリット７のピッチ間隔を上部発熱部５Ａの１／２、下部発熱部５Ｂの肉厚を上部発熱部５Ａの１／２にして、下部発熱部５Ｂの電気抵抗を上部発熱部５Ａの４倍に設定した場合、上部発熱部５Ａの発熱量が下部発熱部５Ｂの４倍となり、図４の酸素濃度と単結晶引上長さとの関係に示すように、低酸素濃度の単結晶が得られることが確認された。具体的には、多結晶質材料４の溶解時において、共通電極８Ａ，８Ｂ間に＋２８Ｖ、下部発熱部電極９Ａ，９Ｂ間に－２８Ｖの電圧を印加して、下部発熱部５Ｂに１２５ｋＷ消費させた結果、多結晶質材料を安定に溶解することができた。また、引上時には、共通電極８Ａに＋２１Ｖ、共通電極８Ｂに－２１Ｖの電圧を印加して、上部発熱部５Ａに７１ｋＷ、下部発熱部５Ｂに１７ｋＷ消費させた結果、半導体単結晶を安定に引上げることができた。このとき、素材チャージ量は７５ｋｇ、引上げられた単結晶外径はΦ２０６ｍｍ、重量は６８ｋｇであった。

【００１６】尚、本実施の形態において、各種数値を上記のように設定してあるが、本発明は引上中の単結晶の

酸素濃度を低くすることを可能とし、さらに、坩堝に保持した多結晶質材料４を安定に溶解することを可能とするものであれば、これら数値条件に限定されることはないことは勿論である。

【００１７】

【発明の効果】本発明は以上のように構成されており、特に、坩堝内での多結晶原料溶解時には、下部発熱部のみを加熱させるため、坩堝に保持した多結晶質原料を下側から徐々に安定に溶解することを可能とする。また、単結晶引上中は発熱分布のピークが上部に位置するように上部発熱部に大きな電力が加わるため、単結晶の酸素濃度を低くすることができ、また、発熱部の酸化による浸蝕を軽減させ、発熱部の寿命を長くすることができる。さらに、装置自体を低コストで且つ設置スペースを最小限に抑えることができる。

【図面の簡単な説明】

【図１】本発明の実施の形態を示した模式的縦断面図である。

【図２】同じく発熱体の斜視図である。

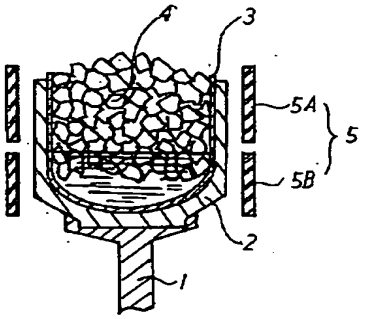
【図３】同じく電流経路の変更手段を構成する変更回路説明図である。

【図４】本発明と従来技術とを比較した酸素濃度と単結晶引上げ長さとの関係を示すグラフである。

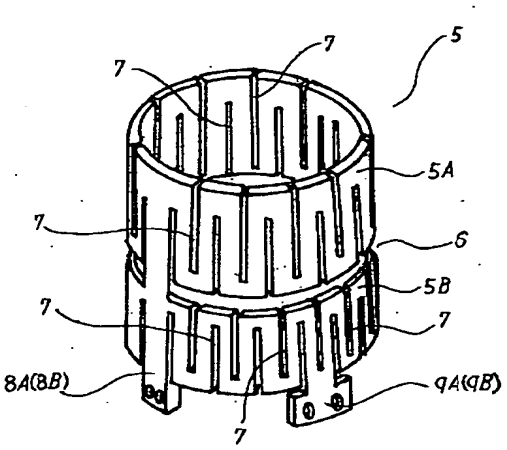
【符号の説明】

１…坩堝軸
２…黒鉛坩堝
３…石英坩堝
４…多結晶質材料
５…発熱体
５Ａ…上部発熱部
５Ｂ…下部発熱部
６…円環状スリット
７…垂直スリット
８Ａ，８Ｂ…共通電極
９Ａ，９Ｂ…下部発熱部電極
１０…変更回路
１５…電源
ａ，ｂ，ｃ，ｄ…サイリスタ

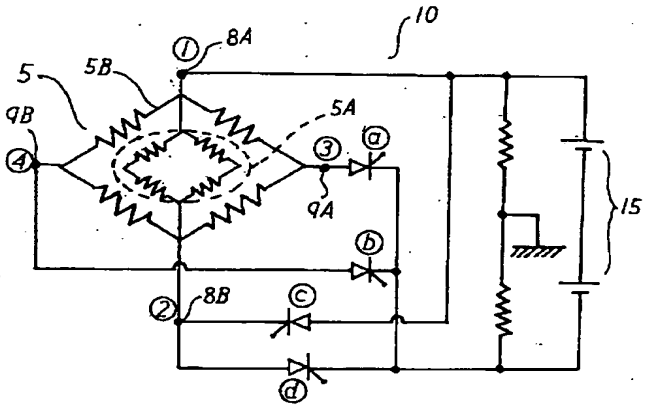
【図１】


4
3
5A
5
5B
2
1

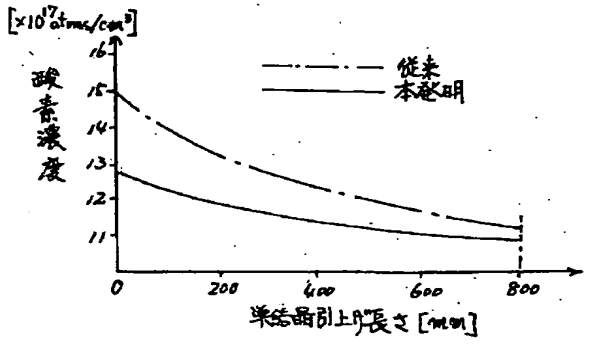
【図２】


7
7
5
5A
7
6
5B
7
7
8A(8B)
9a
9A(9B)
7

【図３】


10
①
8A
5
5B
9B
5A
④
③
ⓐ
9A
ⓑ
②
8B
ⓒ
ⓓ
15

【図４】


[×10¹⁷atms/cm³]
酸素濃度
16
15
14
13
12
11
0
200
400
600
800
従来
本発明
単結晶引上げ長さ [mm]